Sundownloaders, An Interim Report: Science, Intellectual Property, Opportunities.

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Never heard of them! What is a sundownloader? - **Read on!**

The first ideas and models came in 2014, the initial patent application was in early 2015 and a preliminary scientific paper* was published a little later in that same year. Progress thereafter was rapid until COVID-19 caused a hiatus. This truly innovative yet very simple technology can play a significant role in the world's economic and social recovery from the pandemic, so we are now striving to re-invigorate development work, urgently and on a larger scale.

Scientific and Technical Basis:

The greenest invention since chlorophyll[1] redirects sunlight to where it is needed[1] - most obviously to support horticulture but there are many applications including solar electricity. It uses convex reflectors so shaped and oriented that though stationary[1] and non-focussing[1] they provide extra radiation of intensity suitable for plant growth, human enjoyment, etc. Sundownloaders will be inexpensive to make, install and maintain (unlike solar-tracking mirror systems), yet capable of delivering the product (which is simply extra light), without adjustment, for extended periods, even all year. We are at the stage where detailed, expert, but quite predictable engineering skills are needed to develop prototypes such that individual installations can be quickly and easily put together - a combination of varied shapes for the wide range of sites where sundownloaders will be used (details varying with latitude, local topography, and site-specific objectives). High-quality mirror surfaces are not required.

The Appendix† mentions a mathematical, computer-operated method for analysing designs, showing what added sunlight intensities are achievable; and experimental confirmation which offers encouraging prospects. Further improvement is doubtless possible. CAD is in hand.

A formal analysis⁑ has also been undertaken (published online in 2018) of the basic solar science, with surprising results about the quantity of solar radiation according to latitude and season, and especially the benefits of a more-or-less vertical receiving surface such as the sundownloader. Included are analyses of the efficiency of photosynthesis and the prohibitive cost of growing staple foods by the use of artificial light alone. The second link⁑ is to another analysis of a particular published case on vertical farming, with similar conclusions.

Intellectual Property:

Patents have been granted already in Australia, Russia, Europe (EP3242547 B1), China and India with validation under way for most European countries. Korea, USA, Canada, etc. will follow shortly. Attention to other aspects of IP is in hand.

**Solar Radiation Enhancement*, T.R.C. Boyde, *Jacobs Journal of Agriculture* 1(2015)1-4

[1] *You're mad*. See below

† Appendix: follows that.

⁑ *Downloading the Sun,* https://trcboyde.net/downloading-the-sun.html

⁑ *Concept Definition and Economics of Vertical Farming,* https://trcboyde.net/vertical-farming.html

Benefits to Society and the Economy:

Sundownloader businesses will include consultation, installation and maintenance as well as manufacture, logistics, distribution and actual use. We shall introduce a completely new element to the internal economy: what's more and we hope will appear obvious, this will be at quite low capital cost, quick, providing employment to many (with easily-acquired skills), helpful to the most deprived people of all, yet also (if businessmen take advantage of what is on offer) forming the basis of a new export industry to benefit entire countries. Sundownlooaders are i] genuinely environment-friendly and contributory to conservation, ii] allow growing extra food in domestic gardens, greenhouses, even outdoors, iii] at zero electricity cost, iv] and will provide some relief to the national electricity grid - especially valuable because sundownloaders work best when the sun is low (dawn, dusk, winter).

What is needed now:

Rapid progress demands financial input. We estimate that for prototypes to be field-tested in Britain this year will require grant or investment finance of £150,000 - somewhat beyond the inventor's personal resources. We are in contact with Cambridge Rapid Components Ltd (of Haverhill, Suffolk) and believe that they will be able to do what is required, very quickly, but will be obliged to charge on a normal commercial basis.

Looking now at possible private rather than government-grant funding:-

Investors are naturally are a little reluctant to put money into something really new, because it is harder than for existing technology to project how it can be exploited in commerce. A new kind of computer programme or device will attract support, almost for certain, but there has been nothing really new in IT since Sir Tim Berners-Lee invented the world-wide-web over thirty years ago ….. .

You're Mad:

You're saying sundownloaders are as innovative as the world-wide-web? Yes.

But mirrors have been used in gardens for a long time. Yes, for centuries, and there are even patents from much more than a hundred years ago. Likewise electronic computers were known for more than 40 years (and the principles much longer still) before Berners-Lee found a new application.

Stationary mirrors reflecting sun down all day to a fixed spot? You're mad! Mad or not, they work. Yes, the shapes-and-orientations have never-been-seen-before, which is why patents are possible.

So they focus light wherever I want it? Focussing light is good if you want to set fire to something or heat a boiler, bad for keeping a solar panel cool or growing plants. Our aim is sufficient extra, free, natural sunlight when and where most useful, including higher latitudes, dawn and dusk, wintertime. Ten percent of full sun, extra, doubles plant growth in greenhouses: we can do that, most of the year.

What about solar energy? Solar panels oriented to give maximum output at midsummer mid-day work less well when their output is really needed. Our idea is to bring in more light and angle it down correctly just when most useful, including domestic and small-scale installations, including for the poorest people in the poorest countries.

C*ommercial-scale solar energy?* For a solar farm of area measured in hectares, 'extra' light must be proportionately less than in the case of a domestic installation; but better-orienting available light at low-sun times is surely worthwhile - extra wattage just when it is most valuable; near-zero operating cost, etc., etc. - any businessmen out there?

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Appendix: Theory, and an Experiment relating to Type 2 Sundownloader:
The initial concept, Type 1, was of a single wide-sweeping convex mirror of dimensions and curvature suited to the place where installed so as to deflect sunlight directly or obliquely down to the desired target area, and in Type 1B the actual curvature of the mirror surface is peculiar to solar direction at each hour of the day. Working examples of both exist, at model scale or more. It was envisaged from the outset that a multicomponent structure could serve also: this is Type 2, in which many small mirrors (mi-lets) are attached to a frame, itself either flat or curved, the whole being termed a framilet, and the individual mi-lets are themselves ordinarily curved in the same manner as in Type 1.

In the experiment to be described, the mi-lets were overall 20cm square and of uniform curvature such that the range of angles was 20°, equally on both horizontal and vertical axes. Eight or nine mi-lets on a flat frame formed a framilet; three installed over one enclosure such that the centres were ≈3m above the target area, angled slightly downwards and facing East, South and West respectively. Two matched enclosures were used, about 2m square, open above to the sky but the floor always shaded. Light intensity was measured with a Skye Instruments Ltd PAR Sensor in each enclosure, attached to a 'Datahog 2' recorder. Extensive tests had confirmed equality of the enclosures without framilets.

On 22nd October 2019 (in London, 52°N, solar declination -10.8°) PAR was recorded at 30-minute intervals from 0930 to 1730 (each reading is averaged over the previous 30 minutes, not instantaneous). Extra PAR was observed in the active enclosure. Specifically, at 1300 GMT the extra was 132 PAR. For the avoidance of doubt, full results are tabulated below. Average 50.7 PAR extra (equating to 2.9 DLI) was maintained over the whole of a late autumn day which was indeed mostly sunny, but not continuously so.

PAR is 'photosynthetically-active radiation'. The unit is one micromole of such photons, per second, per m^2. DLI is 'Daily Light Integral' = moles of such photons per m^2 over the whole day. 200 PAR or 10 DLI extra will be considered excellent by greenhouse horticulturalists - game-changing - and is surely within our reach, as will now appear.

A computer-based method calculates deflected-light-intensity from values for mi-let curvatures and framilet area, height and angulation. Applied to the circumstances of the above experiment, this method predicted 158 PAR extra at mid-day: the experimental result is 85% of that - startlingly good even though in its present form the calculation method assumes 100% reflectivity of the mirror material and 2000 PAR as the intensity of full sun. Small adjustments in the mi-let design produce much better deflected-light-intensity - changing the range of mi-let angles in the vertical axis from 20 to 7 degrees increases the predicted peak PAR to 397, suggesting a real-life extra DLI ≈ 8.

(2000 PAR can be taken as approximately correct for sun directly overhead and a clear sky but intensity will be considerably less when the sun is lower in the sky due to absorption by a thicker layer of atmosphere. At 12.45 on the day concerned, solar altitude was +26.5°.)

One objective of the desired development programme is a computer-based system for evaluation and prediction of Type 2 designs, largely replacing the present semi-manual means. This should be much quicker, more easily understood by non-mathematicians, and directly convertible into installation design procedures.

EXPERIMENT OF 22ND OCTOBER 2019. (PAR NUMBERS RECORDED THEN).

Skye Instruments Ltd Datahog with PAR sensors numbers ...7 and ….8. Times are GMT. Sensor 7 linked to Datahog port 1 was placed in the North enclosure and output in PAR units appears below as Channel 5; Sensor 8, port 0, South enclosure, results appear as Channel 4. Sensors report at intervals of 30 seconds but Datahog output is average over previous 30 min. Framilets were arranged over North enclosure so as to give best effect at ~ centre of alcove at the following times:-

1] (0.36 sq m) 09.00 - 12.00,
2] (0.32 sq m) 11.00 - 14.00,
3] (0.36 sq m) 13.00 - 16.00 (areas are totals of the mi-lets composing that framilet).

No sun reached the first framilet until after 0930. Each 'alcove' was approximately 2m square, i.e 4 m^2; and they were previously shown to be equal without framilets. Weather not observed personally, described as generally good. Obviously sun was not continuous and indeed there must have been heavy cloud throughout 11.00 - 11.30

Totals over the whole day, no selection of periods, show that framilets more than doubled incident radiation, delivering over the day almost 3 DLI extra (*in late October*!). As commented elsewhere, this performance can surely be improved upon.

TIME	CH. 4 CONTROL	CH.5 FRAMILETS	EXTRA PAR (average over 30 min)
10:00:00	4 0000041.28783	5 0000044.82222	4
10:30:00	4 0000058.18796	5 0000066.99004	9
11:00:00	4 0000063.48163	5 0000117.59390	54
11:30:00	4 0000048.46402	5 0000055.36946	7
12:00:00	4 0000073.43204	5 0000169.15660	96
12:30:00	4 0000072.01662	5 0000187.33170	115
13:00:00	4 0000067.37404	5 0000199.53900	132
13:30:00	4 0000065.84538	5 0000195.05960	129
14:00:00	4 0000059.24952	5 0000157.12100	98
14:30:00	4 0000054.93249	5 0000129.14290	75
15:00:00	4 0000048.64802	5 0000100.36340	52
15:30:00	4 0000040.72166	5 0000072.45686	32
16:00:00	4 0000024.69910	5 0000030.46823	6
16:30:00	4 0000011.81876	5 0000014.68314	3
17:00:00	4 0000003.45363	5 0000004.12158	0
17:30:00	4 0000000.18400	5 0000000.21467	0
TOTALS	733.7	1544.5	
Average (8 hours)	45.8	96.5	50.7 = 111% extra
			= 2.92 DLI extra